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THE SUCCESSES OF PARTICLE PHYSICS WERE HONOURED AT SPOLETO FESTIVAL OF 2WORLDS

Interview with Fabiola Gianotti, CERN Director-General, and Peter Higgs, 2013 Nobel Prize in Physics, together with François Englert, for the theoretical prediction of the mechanism that gives mass to elementary particles.

"Art and science are not separate universes": this is how Fernando Ferroni, INFN president, describes "The mistery of the origin. Myths, transfigurations and science", a virtual and immersive installation produced by Foundation Carla Fendi in collaboration with INFN and CERN for Spoleto 61 Festival of 2Worlds. The installation offered, from July 1 to 15, a trip throughout the history of our universe: from the Big Bang to the formation of galaxies, black holes, stars, planets, all the way down to our solar system. It gave the visitors a chance to discover some of the instruments employed today to explore the universe, from space telescopes, to neutrino and dark matter detectors of INFN Gran Sasso National Laboratories and to the major experiments at CERN Large Hadron Collider.
Foundation Carla Fendi, which for the first time this year has hightlighted science in Spoleto Festival of 2Worlds, awarded the "2018 Carla Fendi Prize" to Peter Higgs and François Englert, 2013 Nobel Prize in physics winners for the prediction of the mechanism that gives mass to elementary particles, and to Fabiola Gianotti, CERN Director General, for her important role and her contributions in the field of experimental particle physics. The Prize has to be devolved to activities that encourage and support science dissemination. During the Prize Award Ceremony, that took place on July 15 in Spoleto, we met Peter Higgs and Fabiola Gianotti.

Fabiola Gianotti, you are leading the largest particle physics laboratory in the world, CERN, what does it mean to lead such an important laboratory, which is trying to push beyond the frontiers of our knowledge every day?
It is a great privilege, a wonderful and extremely enriching experience. The scientific programme is exciting; from the LHC, which allows us to explore the so-called "energy frontier", to the injection

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projects, such as the Antiproton Decelerator, the only structure in the world dedicated to the study of antimatter, and ISOLDE for the production of radio-isotopes. It is also a privilege to be able to work on a daily basis with scientists from all over the world. I think CERN is not just a school of physics, but also a school of life. At least for me, it has been a school of physics and life since the first day I arrived here as an undergraduate student.

How do you define an effective strategy for a laboratory like CERN, which has to continue to produce revolutionary results, such as the discovery of the Higgs Boson?

I think the best scientific strategy today lies in the diversity of projects. There are still a lot of complex questions open in fundamental physics and there is no single instrument that can guarantee to answer them all. The best we can do is to use the whole set of experimental approaches that particle and astroparticle physics have developed over the years, also thanks to the significant progress in technology. CERN is specialised in the construction and operation of accelerators, which over time have been and continue to be among the most effective instruments for exploration in fundamental physics. LHC allows us to explore the highest energies directly, and the numerous injection projects exploit lower energy beams, but with high intensity, to deal with open questions in a way that is complementary to LHC. It really is crucial to keep as wide a programme as possible, because we don't know where the new physics is, in terms of energy scale, pairing with known particles. We therefore have to look in all possible directions. Obviously, it is fundamental to follow other approaches as well, such as projects for exploring the cosmos and experiments in underground laboratories like the INFN Gran Sasso National Laboratories, which make it possible, for example, to look for and study dark matter jointly with the accelerators.

How far are we, up to now, in our understanding of particle physics? And what is CERN aiming at?

We have taken enormous steps forward. With the discovery of the Higgs Boson, we have completed the Standard Model and, over the decades, experiments at CERN and other laboratories all over the world have allowed us to verify this theory with the utmost precision. But we also know that the Standard Model is not the final theory of elementary particles, because it does not explain open questions such as the nature of dark matter or the origin of the asymmetry between matter and antimatter in the universe. So the current challenge for CERN and other laboratories in our field is to find new physics.

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CERN is also focussing on a major upgrade of the Large hadron Collider. What is HiLumi LHC? How does it differ from the current LHC?

HiLumi LHC is an upgrade of LHC which will allow us to increase the instantaneous luminosity of the beams by a factor of around three compared to current luminosity (therefore reaching a value of 5-7 x 10^{34} $cm^{-2}s^{-1}$) and will enable ATLAS and CMS to record an amount of data around ten times greater than that of LHC. HiLumi LHC will start up in 2027 and will terminate in 2037. This unprecedented amount of data will allow us, amongst other things, to make more precise measurements of the properties of the Higgs boson, including its pairing with second generation fermions, through the decay into two muons, and to extend the potential for discovery in the new physics of around 20-30%, in terms of mass of new particles.

What advice would you give to a young physicist willing to make a significant contribution in a major scientific collaboration? What attitude should he or she adopt?

My first thought would go, above all, to what is the best strategy for enabling a young person to undertake a brilliant career in our field. My advice would be to work on more than one aspect of the experiment, from construction and/or operation of the detector to data analysis, so as to acquire a varied skillset and grow “allround”.

Gaining access to a major project may seem difficult, but during my long experience in one of the LHC experiments, ATLAS, where I started to work as a young post-doc, I have seen hundreds of young people establish themselves brilliantly. Ideas (for example on how to develop a new analysis or how to solve a technical problem with a detector), determination and the desire to learn are the greatest assets and they are noticed and acknowledged in major joint projects.

Peter Higgs, after almost 50 years from the formulation of the theory of the mechanism that gives mass to elementary particles, you have witnessed its experimental confirmation. What would you say to a young theoretical physicist who’s willing to reach such an ambitious goal? What should his attitude be like?

My recommendation to a young theoretical physicist is always to keep his/her view of the various aspects of theoretical physics broad. In my personal experience, the work, which I was involved in, was producing a theory inspired by something that had been successful in an apparently quite different area. It was essentially just a version of a successful theory of superconductivity, that’s the phenomenon where at low temperatures certain materials lose their resistance to the flow

of electricity. And somewhat ironically the successful experiments at CERN involving LHC were dependent on their ability to use superconducting magnetic materials in the magnets. So, my advice to the theorists is to keep their view of the subject broad because what has been successful in one area of physics might transfer to another area. And that is what happened to me.

On 4 July 2012, the ATLAS and CMS experiments at CERN announced the discovery of the Boson that you theorised in the 1960s. What were the feelings associated with the announcement of the discovery? How did you feel?

For years I had been aware that the "boson" would have been detected once the Large Hadron Collider (LHC) at CERN, the machine built with the discovery in mind, was turned on. I had to face up to the fact that what I had done in 1964 was going to change my life. So, it was a rather difficult experience to go through it and I think it showed on the film that was taken at the time. The film is "Particle Fever" and it includes the footage of the announcement at CERN and, it shows very clearly the emotions involved at the time of the announcement. ■